FABRICATION AND DELIVERY OF NON-DESTRUCTIVE READ OUT MEMORY BUFFERS USING LAMINATED LAYER TECHNIQUE

First Quarterly Progress Report

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I. INTRODUCTION

The general objective of Phase I of this program is to explore materials and processing techniques useful in the development of low cost, non-destructive readout buffer memory planes, which are susceptible to batch or continuous processing techniques. Our approach is to explore the use of metallic magnetic alloys that are rolled into foil sheets approximately six to ten microns thick. This foil approach is a non-vacuum technology, except for the preparation of the starting raw materials. During the first quarter of this program, we have prepared foils with five different compositions, assembled magnetic anneal equipment, established photo-etching and laminating facilities, and constructed magnetic parameter measuring equipment. This report describes and illustrates this progress. The reader will be aided by visualizing a miniature processing line that begins with raw materials preparation and ends with magnetic tests. One objective of this processing line, of course, is to establish correlation among materials composition, processing variables, crystallographic structure, and magnetic parameters. This information then will be used in Phase II in memory cell device design.

II. MATERIALS AND PROCESSING

A. Composition of Alloys -

Three alloys were chosen for initial investigation:

Alloy #1	81.5% Ni, 18.5% Fe.
Alloy #2	4% Mo, 79% Ni, 17% Fe.
Alloy #3	3% Co, 80% Ni, 17% Fe.

These alloys are commonly used in small signal magnetic applications and were selected to determine if more careful control of composition and fabrication procedures would result in magnetic properties that are significantly more uniform than the properties of commercially prepared material.

In addition to the above alloys, foils of pure iron and pure nickel were also prepared for comparison purposes.

Final analysis for trace impurities will be performed after heat treatment to eliminate undetected contamination.

B. Melting Procedure -

The starting metals used in the above alloys were rods of high purity iron, nickel, molybdenum and cobalt, all of which had been triple pass zone refined. Eighty gram charges of the alloys were weighed on an analytical balance and then arc melted in an argon atmosphere to consolidate and homogenize the alloy.

The alloys were in the form of rods after arc melting, were then placed in a zone refining apparatus (see Fig. 1) and then double pass zone leveled and vacuum degassed. After zone leveling, the rods were in the form of rods approximately one-half inch in diameter by six inches long.

C. Rolling and Slitting Schedule -

The alloy rods were cold rolled on a two-high Stanat rolling mill (see Fig. 2) to tape 0.008 in. thick, slit to the desired width (1/4-1/2 inch) and re-rolled on a four-high Stanat mill to a thickness of 0.002 inch. The tape was taken to a Sendzimer mill and further rolled to 0.0005 in. thick. Samples of the tape were taken at various thicknesses for magnetic and metallurgical tests.

During the rolling sequence, the tape did not receive any intermediate stress relief anneal which might have caused contaminants to diffuse into the alloy.

During rolling the tape experienced a 99 percent reduction in area which is a relative measure of the deformation energy contained in the sample. The deformation energy in turn influences the annealing kinetics of the foil.

Fig. 3 is a photograph of foils of various thickness and width; the wide foil on the right is 0.0005 in. thick and 4 inches wide.

D. Annealing -

The main reason for annealing the foil is to eliminate the strain energy of deformation, and thereby reduce the coercive force and increase the switching speed of the foil.

In some applications it is desirable to induce a magnetic uniaxial anisotropy in the foil. This can also be accomplished in the three alloys under investigation by cooling the foil from the annealing temperature through the Curie temperature, in the presence of an orienting magnetic field.

The furnace in which the annealing is performed is shown in Fig. 4. It is capable of reaching 1200°C, although best results from annealing permalloy have so far been achieved by holding 1 hour at 1050°C. An Inconel retort is shown in the furnace in Fig. 4 which permits anneals to be carried out in inert, oxidizing or reducing atmospheres.

The orienting magnetic field is supplied by an auxiliary winding wrapped on the rectangular muffle shown in the furnace. It is capable of producing a 15 oersted D.C. magnetic field within the furnace.

Experiments are still under way to determine the best combinations of annealing times and temperatures (and magnitude of orienting field when an easy axis is desired).

E. Laminating -

One of the advantages of fabricating memories from mounted planar foils of permalloy is that it is possible to change the geometry of the final memory bit without changing the technology of mounting the permalloy foils. For example, the two memory designs submitted in the proposal for this contract can be constructed by stacking layers of a copper-clad dielectric, a dielectric clad with permalloy on both sides, and another copper-clad dielectric. The only difference in fabricating the two designs is in the photo resist artwork. In fact, it is possible to think of other designs which can also be made from the same combinations.

We are studying the lamination of permalloy and copper sheets on various dielectrics. The laboratory press we are using is shown in Fig. 5. It is a standard laminating press capable of both heating and cooling cycles.

There are two general approaches to the laminating procedure:

1. Laminate the foil in the as-rolled condition and then anneal the mounted foil. The advantage of this technique is that the foil can be easily handled after annealing without straining it. The disadvantage, of course, is that both the dielectric substrate and the adhesive must be capable of withstanding the annealing temperature of 1,000°C.

2. Anneal the foil and then laminate to a substrate. The advantage of this technique is that one has a wider range of adhesives and dielectrics from which to choose. The disadvantage is that one must be careful to minimize straining the foil during lamination as one must be careful to ensure that if strain does occur, it is uniform over the plane of the foil.

F. Photo Etching -

Samples for magnetic testing are prepared by photo etching techniques common to the solid-state electrical field. A photo resist coated laminated foil undergoes ultra-violet exposure through a mask. After developing the photo resist, the operator immerses the laminated foil into an etching bath where chemical milling takes place.

Uniform coats of photo resist are spread over the laminated foil by centrifugal force spinning (see Spinner in Fig. 6). The artwork used to prepare ultra-violet exposure masks is shown in Fig. 7, and an etched circular specimen in Fig. 8.

III. TEST APPARATUS

Two basic pieces of magnetic test apparatus are available for characterizing the hysteresis loop and switching speed of the processed foil. The magnetic hysteresis loop tracer is shown in Fig. 9, and a typical hysteresis loop obtained with this apparatus in Fig. 10. The switching speed apparatus is shown in Fig. 11. These pieces of equipment are similar to equipments at Georgia Tech and NASA Huntsville, and will greatly aid the interchange of information among the several groups of workers.

Electronics modules that will drive and sense the final prototype memory plane are shown in Fig. 12.

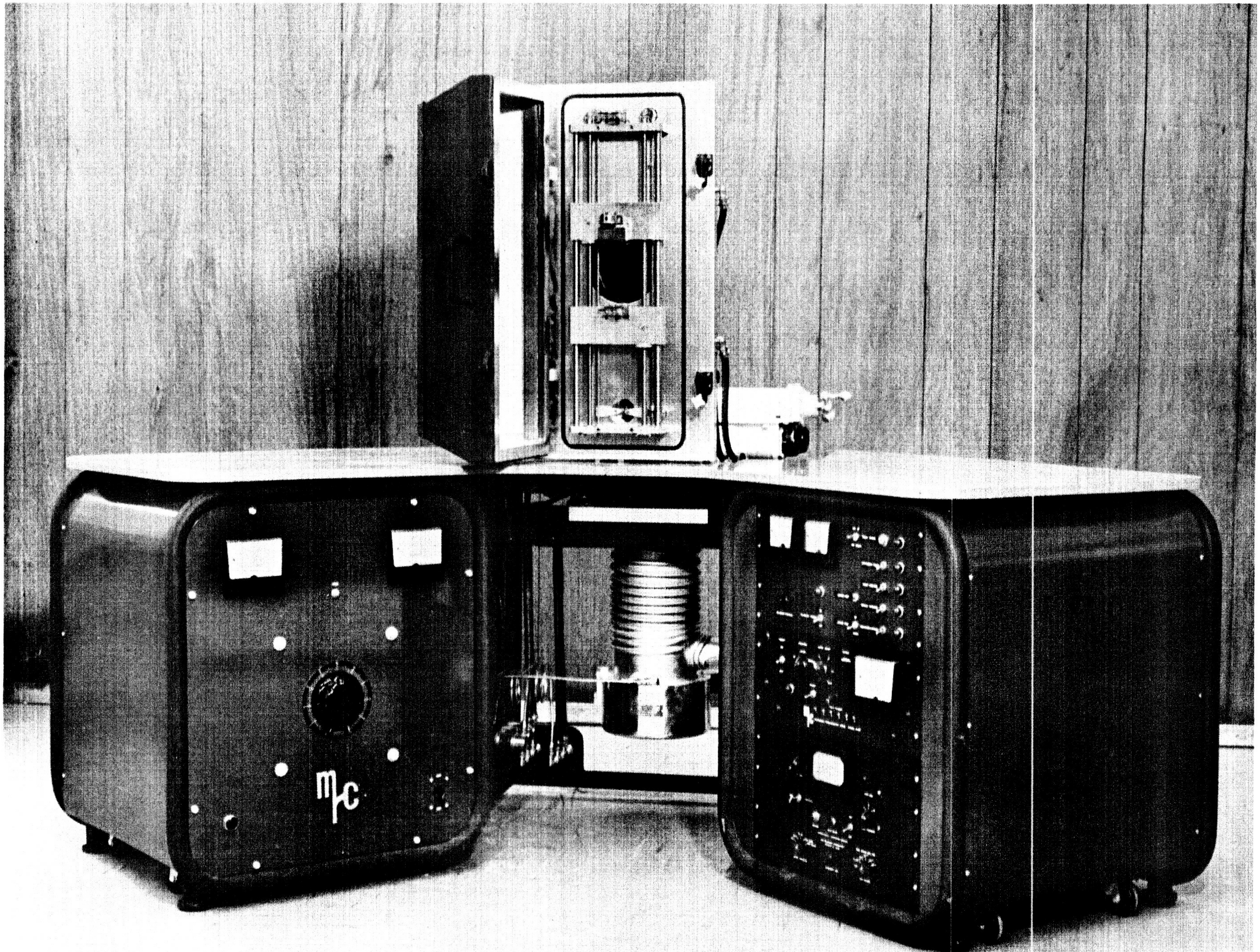
IV. PLANS FOR THE NEXT QUARTER

During the next quarter, we will emphasize magnetic parameter testing of the foil materials. Coercive force, squareness ratio, switching time and output signal data will be correlated with the materials and processing variables. These measurements will yield information useful in selecting the process variables most useful in the design and fabrication of the prototype memory cells.

Laminating techniques also will undergo further study. Insulating backing materials, adhesives, and heat treatment must be combined into a process that yields minimum strain induced non-uniformity in the memory cells.

In addition to the magnetic measurements and laminating procedures, memory cell design and fabrication will commence in the next quarter. The knowledge of anisotropy field, dispersion, and coercive force obtained from measurements on the prepared foil will be used in the design work.

Two designs are available for the non-destructive readout mode. The first design requires that the magnetic foil have very small dispersion and that the anisotropy field be uniform for all elements. With the foil spots magnetized along their easy axes, a reversible partial rotation of the magnetization vector will result when the word line is energized in the difficult direction. The second design uses a double element, with the anisotropy in one of the foil spots being about ten times larger than in its superposed neighbor. In effect, the high anisotropy spot serves as a permanent magnet, while the low anisotropy spot serves as a read-out and as a keeper to provide a return flux path. The choice of any given memory cell geometry depends upon, among other factors, the uniformity of magnetic properties in the starting foil material.



ELECTRON BEAM FLOATING ZONE REFINER
MRC MFG. CORP. MODEL EBZ-93

Figure 1
Zone Refining Apparatus

Figure 2
Rolling Equipment

Figure 3
Prepared Foils

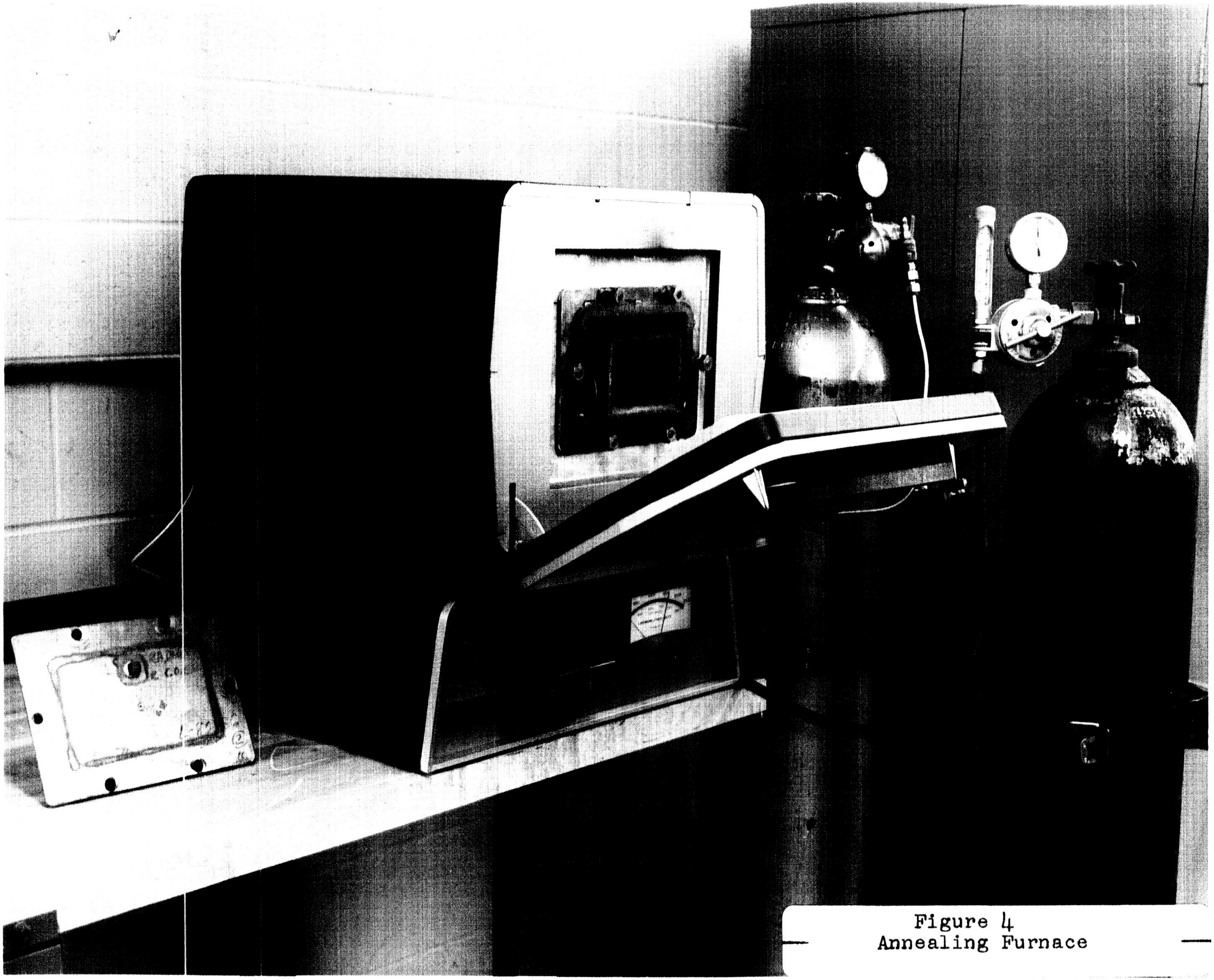


Figure 4
Annealing Furnace

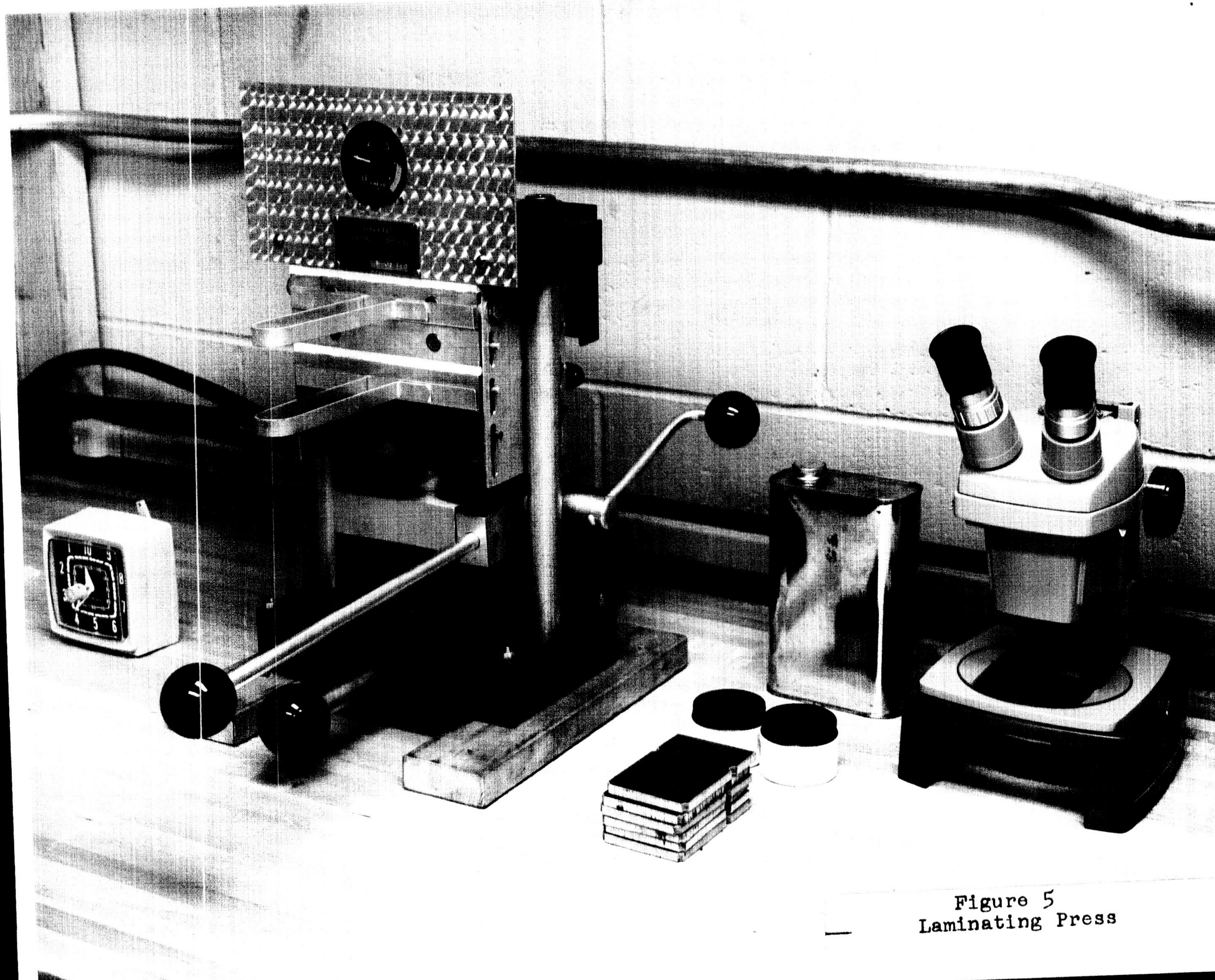


Figure 5
Laminating Press

Figure 6
Photo Resist Spinner

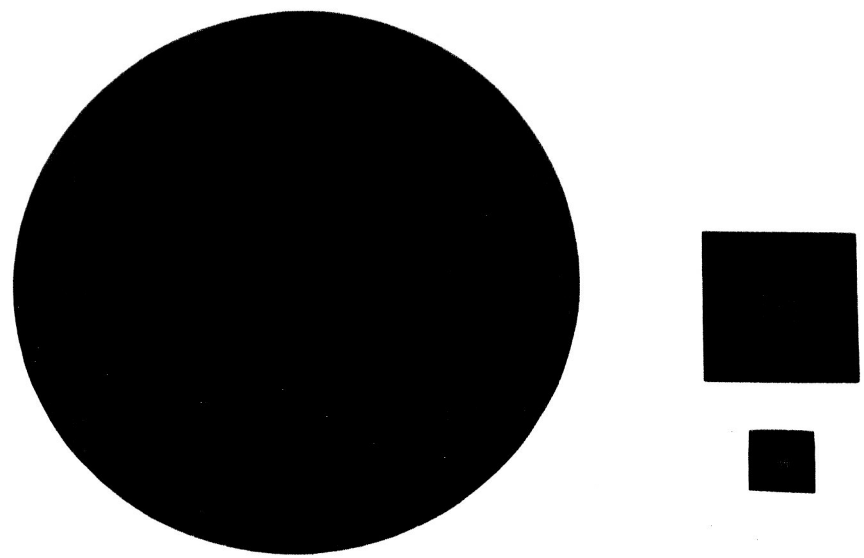


Figure 7
Photo Etching Artwork

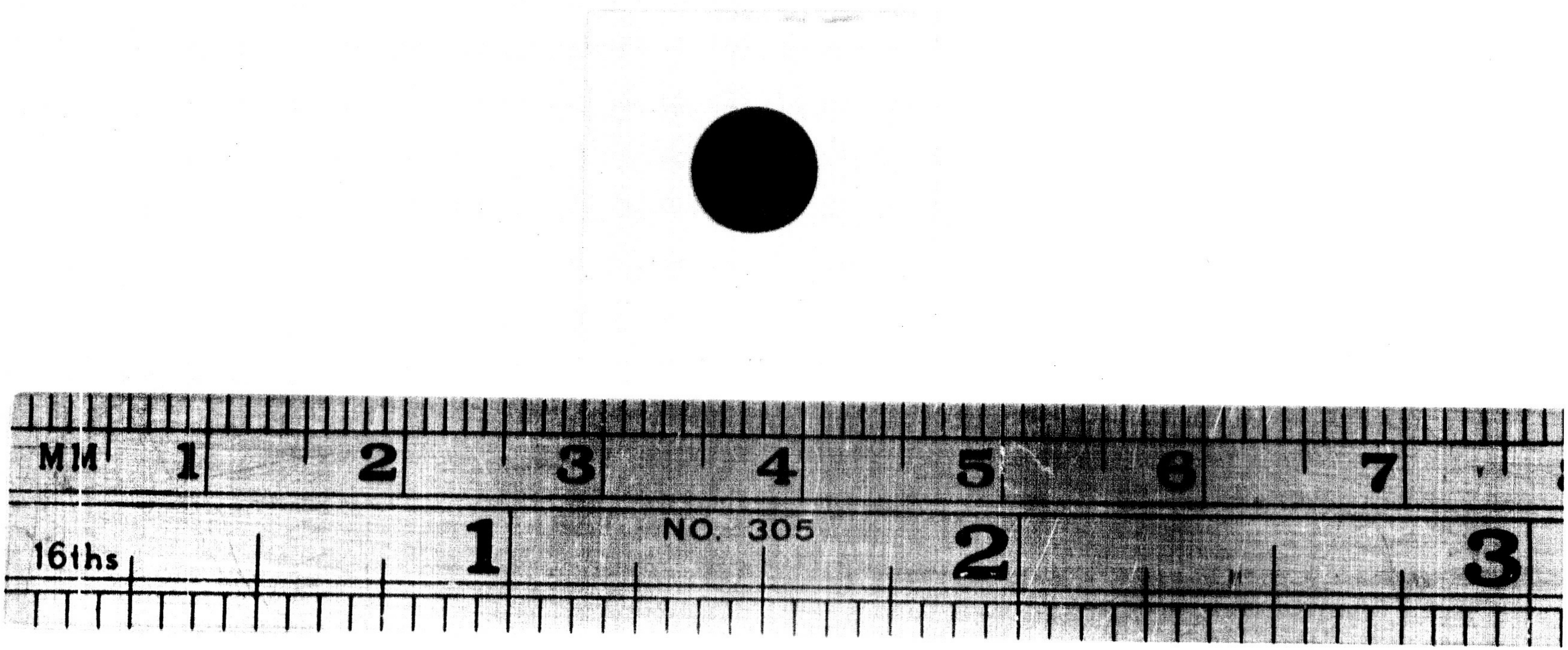


Figure 8
Magnetic Test Specimen

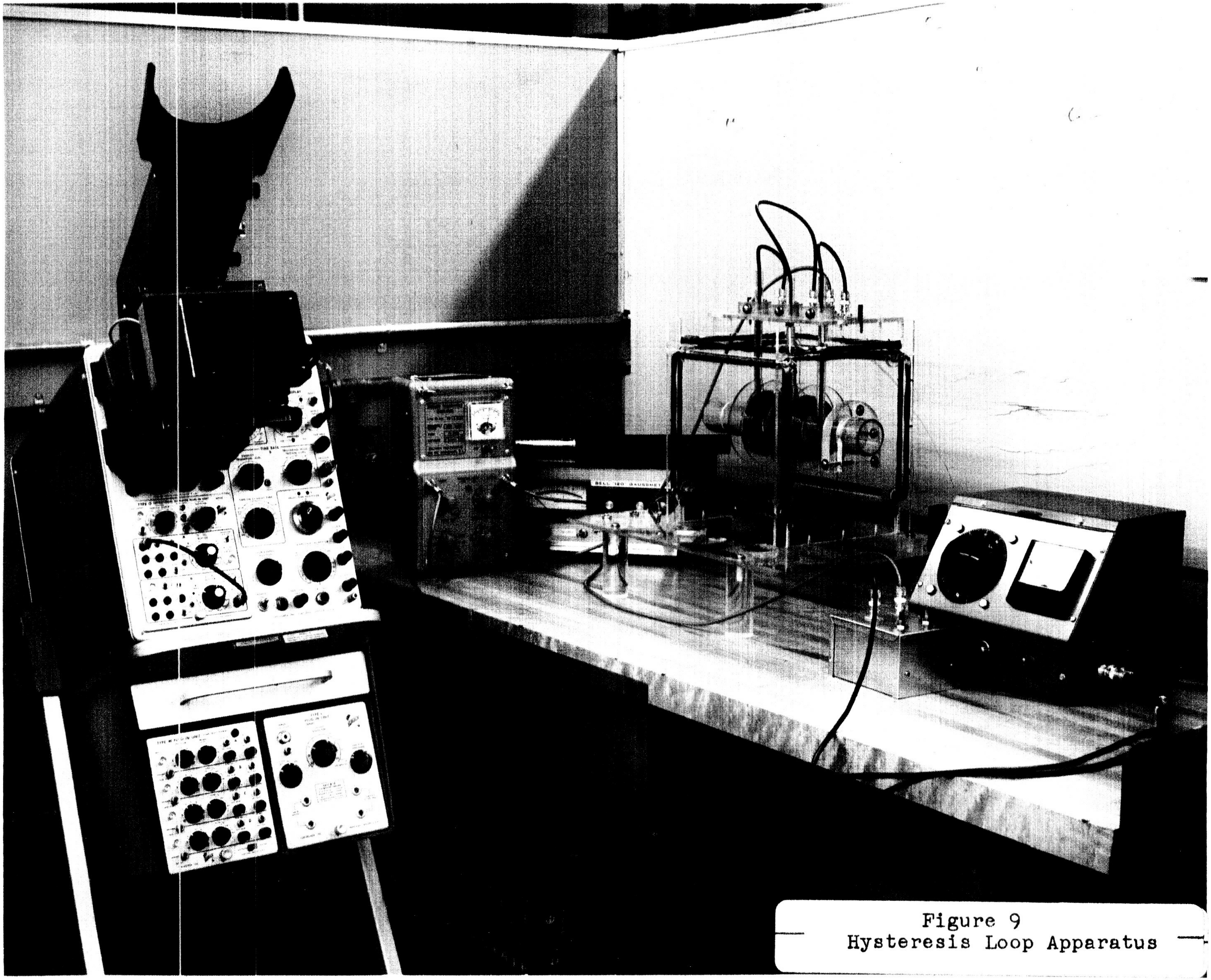


Figure 9
Hysteresis Loop Apparatus

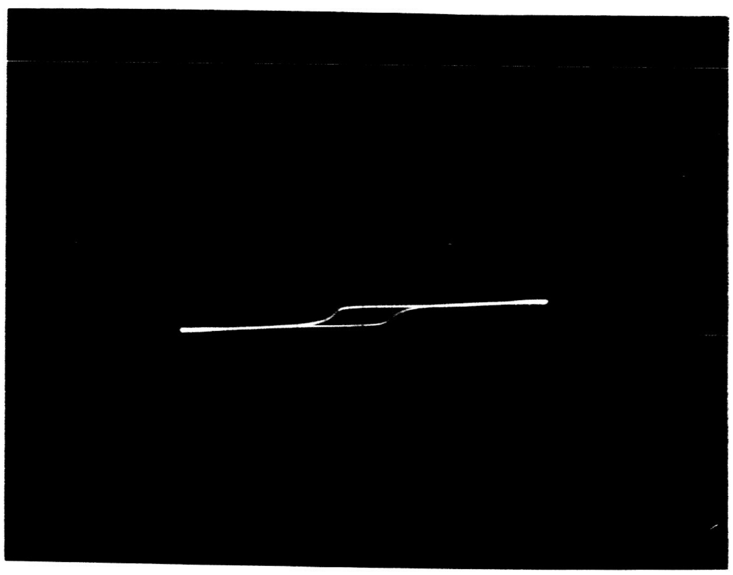


Figure 10

Hysteresis Loop

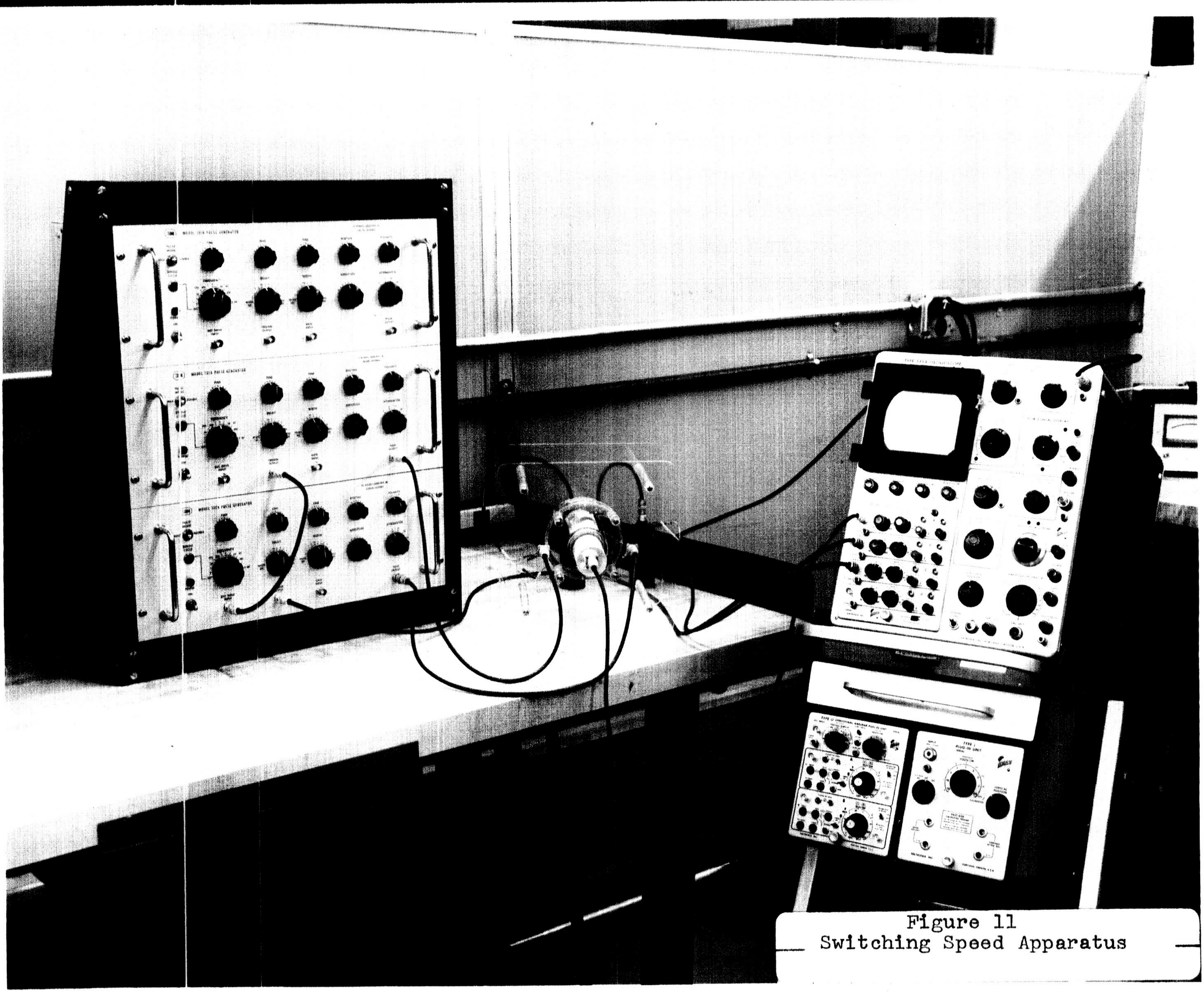


Figure 11
Switching Speed Apparatus

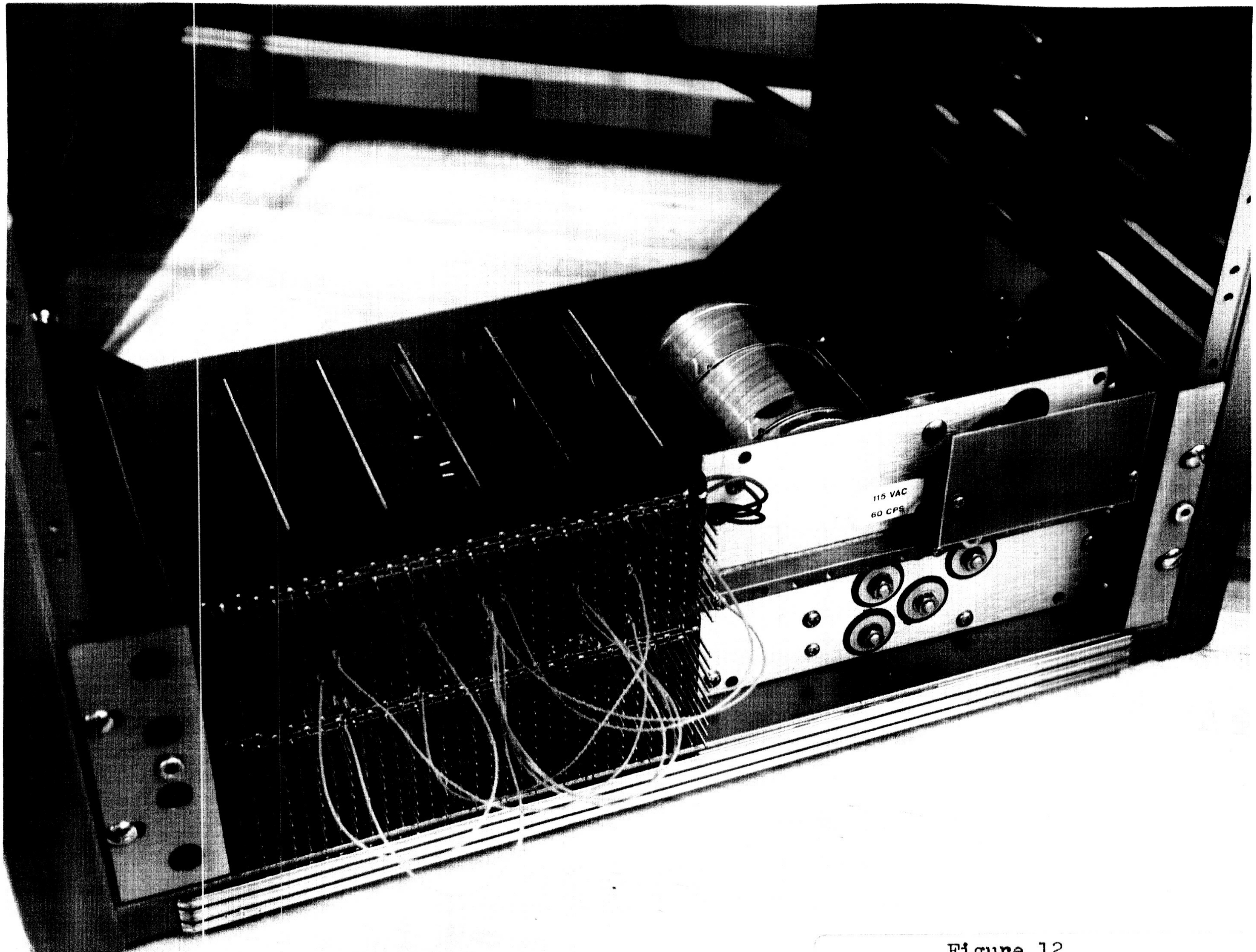


Figure 12
Electronics Modules